REPORT OF SURVEY CONDUCTED AT

GENERAL TOOL COMPANY
CINCINNATI, OH

OCTOBER 2002

Best Manufacturing Practices

1998 Award Winner

INNOVATIONS IN AMERICAN GOVERNMENT

BEST MANUFACTURING PRACTICES CENTER OF EXCELLENCE
College Park, Maryland
www.bmpcoe.org

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
01OCT2002	N/A	-

Title and Subtitle BMP Report of Survey Conducted at General Tool Company, Cincinnati, OH	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Best Manufacturing Practices Center of Excellence College Park, MD	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es)	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
The original document contains color images.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
32

Foreword

This report was produced by the Office of Naval Research's Best Manufacturing Practices (BMP) Program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective toward this goal is simple: to identify best practices, document them, and then encourage industry and government to share information about them.

The BMP Program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas which are highlighted in the Department of Defense's 4245.7-M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource in helping companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to learn from others' attempts and to avoid costly and time-consuming duplication.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at the General Tool Company, Cincinnati, Ohio, conducted during the week of October 7, 2002. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from industry, government, and academia throughout the U.S. and Canada – *so the knowledge can be shared*. BMP also distributes this information through several interactive services which include CD-ROMs and a World Wide Web Home Page located on the Internet at http://www.bmpcoe.org. The actual exchange of detailed data is between companies at their discretion.

General Tool Company is one of the few job shops in the United States that can perform a full range of metal-working to the exact standards of aerospace and defense customers, and continues to remain competitive within commercial markets. General Tool Company's policy is to manufacture, fabricate, assemble, and deliver products and services that meet the customers' specifications, drawings, and contractual requirements. Among the best examples were General Tool Company's accomplishments in centralized tooling and Cribware sofware, Friction Stir Welding, clean room facility, non-conventional methods that use a Laser Tracker, and roof mist cooling.

The BMP Program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on the General Tool Company expand BMP's contribution toward its goal of a stronger, more competitive, globally-minded, and environmentally-conscious American industrial program.

I encourage your participation and use of this unique resource.

Anne Marie T. SuPrise

Anne Marie T. SuPrise, Ph.D.
Director, Best Manufacturing Practices

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Report Summary

Background

In 1947 shortly after World War II, General Tool Company (GTC) was developed in Cincinnati, Ohio with a few dozen small machines and only five employees. Businesses were growing and changing from war effort companies to commercial concerns and William Kramer, Sr. and Harold Poe found a real market for producing machinery and parts. Shortly after their business began, GTC started working with Procter and Gamble producing thousands of metal shear pins that were used to protect Procter and Gamble's large product manufacturing machines. GTC then began working with stainless steel, which developed its business with General Electric (GE) in 1948. By 1949, GTC added a second work shift to help with the growing projects. In 1957 at the age of 17, William Kramer, Jr. began working part time for GTC, and in 1965 became president. Since the beginning, GTC has served over 60 valued customers including Lockheed Martin, NASA, GE Aircraft Engines and Medical, Rolls Royce, and Pratt & Whitney; increased its number of job shops to two; and developed a well educated, informed and productive staff. GTC gained ISO-9001 certification in 1996, which stands the company in the front for precision machining, fabrication, tooling, die, and mold, and assembly capabilities for worldwide applications. In March 2001, several of GTC's employees received Outstanding Achievement Awards from program partner, Lockheed Martin Space Systems Company, for the precision machining and on-time delivery of "mission critical" parts for NASA's Space Shuttle Program.

GTC has been in business for 55 years and is now a medium-sized job shop with 220 employees, achieving $32 Million in annual revenue for 2002, and projecting $40 Million annual revenue for 2003. GTC is certified by the National Aerospace and Defense Contractors Accreditation Program and is AS-9000 and ISO-9001 certified. GTC's facilities include a 200,000 square foot job shop in Cincinnati and a 40,000 square foot job shop in Woodlawn for tooling and assembly business units. The facilities include 40-ton lifting capacity, gas turbine test cell, Class 10,000 clean room, and a full nondestructive testing facility. GTC is one of the few job shops in the United States that can perform a full range of metal-working to the exact standards of aerospace and defense customers. GTC continues to remain competitive within commercial markets with its policy to manufacture, fabricate, assemble, and deliver products and services that meet the customers' specifications, drawings, and contractual requirements. GTC's top priority is customer success and satisfaction, which has allowed the company to grow internally and nationally. Through this, GTC has become one of the largest and best equipped manufacturers of engineered systems in the country.

GTC has continued excellence in performance through its partnerships, programs, machines and enhanced facilities. Among the best practices documented by the Best Manufacturing Practices survey team were the implementation of centralized tooling and Cribware software for controlling inventory and documenting the tooling requirements associated with specific jobs; friction stir welding for aluminum as an alternative to conventional weld processing; clean room facility that provides the job shop with additional capabilities for cleaning, assembling, and packaging processes; nonconventional methods that use a Laser Tracker, an articulated computerized inspection arm, and out-of-cycle dimensional measurements; roof mist cooling to provide additional cooling for the machine shop; and certification to program standards that introduced tighter process control for nondestructive testing.

GTC has many plans for the future. The company is striving to strengthen its competitiveness in the commercial market by searching for new ways to meet the market's needs and is willing to restructure to meet them. GTC strives to maximize service to specific clients within selective industrial markets. The company's production and development hardware has allowed them to support clients development and production activities through tailored approaches to multiple lines of business. Also, GTC's program management reduces client administrative involvement. GTC's focus is on the implementation of programs such as composite machining, in field defects, customer feedback, intranet, and performance management and review system as well as others. Through all this, GTC has advanced its high standard of performance and customer success. The BMP survey team considers the practices in this report to be among the best in industry and government.

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Section 2

Best Practices

Production

Centralized Tooling/Cribware

General Tool Company has integrated its tooling, engineering, and programming functions in conjunction with the implementation of Cribware software and has experienced annual savings of approximately $300,000 per year.

General Tool Company (GTC) was maintaining a $600,000 tooling inventory that contained a large number of obsolete and infrequently used tools. In addition, while tool crib software was being used, it was out of date and contained corrupted data. As a result, special tools were insufficiently tracked, which led to them often being misplaced and inappropriately reordered for subsequent jobs.

GTC entered into an integrated supply agreement with Dayton Supply and Tool (DST), which included the installation and maintenance of Cribware software for controlling inventory and documenting the tooling requirements associated with specific jobs. DST provided the software, user training, and system implementation as well as worked with GTC to update the existing tooling database, barcode the tooling inventory, purge the existing inventory of obsolete tooling, and provide a means to prepare and track tool kits.

This upgrade of the tool crib operations also gave GTC the opportunity to standardize the indexable tooling, performance drills, and carbide milling cutters as well as reduce inventory. In addition, the tool tracking capability led to the ability to balance tool purchasing with tool consumption and to identify usage by department, task, individual, etc. This led to a significantly reduced expendable cost per manufacturing hour and an improved job estimating capability. Cribware software has experienced annual savings of approximately $300,000 per year.

Deep Pocket Milling

General Tool Company used high speed machining technologies to reduce the machining time by approximately 75% and improved the part quality, which reduced the downstream finishing and assembly operations by 50%.

General Tool Company (GTC) recently completed the fabrication of a series of large components for the National Ignition Facility at the Lawrence Livermore National Laboratory (LLNL). These 60 x 80 x 19 inch components were machined from a 6061 aluminum alloy casting with approximately 0.75 of an inch of machining stock. The average wall thickness on the 10 through-windows was 0.390 of an inch, with an accompanying opening tolerance of +/- 0.009 of an inch and a surface finish requirement of 32 RMS.

The initial fabrication process was based on a horizontal-boring mill with a 1,100-rpm spindle. This approach required multiple setups, elaborate clamping and vibration devices, and a rough machining stage. The best machining time achieved was 80 hours per part and was accompanied by inconsistent size control, a poor finish, excessive cycle time, and cost overruns in down stream finishing and assembly operations.

GTC resolved these problems by moving the job to a machine with an 8,000-rpm spindle. A 19 inch cutter with polished, round inserts (see Figure 2-1) was used to finish machine the window sections in a single set up (after the

- ❑ After the corners were cleared, the copy mill extended 19-1/4"
- ❑ Holder and tool balanced at 8000 RPM
- ❑ Copymill uses 0.472" positive, polished inserts

Figure 2-1. High Speed Cutter

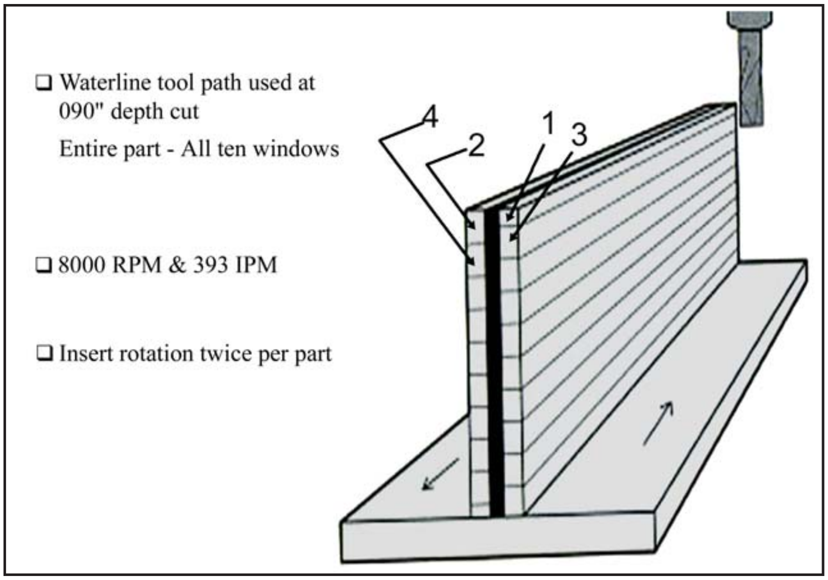

Figure 2-2. Machine Tool Path

corners were cleared in a preliminary operation). The machine tool path was a waterline or thin-to-thick configuration (see Figure 2-2) with a relatively light depth of cut (0.090 of an inch) and a 393 inch-per-minute feed rate.

GTC's high speed machining technologies reduced machining time by approximately 75%. This throughput increase has allowed GTC to fulfill its commitments to customers. The high speed machining also improved part quality, which reduced downstream finishing and assembly operations by 50%. These machining practices can also be applied to similar future parts.

Friction Stir Welding for Aluminum Alloys

Friction stir welding is a new joining technology that is being pursued by several industry sectors to enhance material properties, improve fabricability, and boost affordability to meet ever increasing design requirements for new products. General Tool Company has taken the initiative to embrace this new technology.

General Tool Company (GTC) obtained a job to produce a number of large units for the National Ignition Facility of the Lawrence Livermore National Laboratory (LLNL)/University of California. 194 units were to be produced during a two-year period at a value of $12 Million. This job opportunity represented a significant portion of business for GTC. The job, as originally quoted, consisted of producing a box type assembly made from 356-T6 aluminum alloy casting. This required a huge casting of inconsistent quality to be precision machined extensively to achieve the final product shape and configuration. In an attempt to reduce the cost and enhance the quality of the units, GTC suggested producing the units as a weld fabricated assembly using extruded shapes and plates of 6061 aluminum alloy. An estimated $1 Million was saved by producing the units as a welded fabrication. However, producing a weld fabricated assembly from aluminum presented a number of challenges. Items to be considered were the employed welding process, weld quality, distortion, inspection, and possible repair/rework schemes. Several conventional arc welding and high energy density weld processes were considered (e.g., plasma arc welding, gas tungsten arc welding, gas metal arc welding, electron beam). The merits of each of the weld processes were evaluated with respect to the other items mentioned.

GTC became aware of a new welding process, Friction Stir Welding (FSW) developed by The Weld Institute in Great Britain, as a method of fabrication. The process can create weldments in aluminum alloys with enhanced mechanical properties and less distortion compared to conventional welding processes. FSW is accomplished by frictional heating caused by a rotating tool that is plunged into the seam of a weld joint and traversing it along. As the tool is rotating and traversing, the base material is frictionally heated to a temperature in which the material can be plastically deformed and forged, thus producing coalescence between the materials to be joined.

GTC embraced the FSW process. Because there was no affordable or quick commercial source for FSW equipment, GTC, using its knowledge of machining equipment and resources, designed and built an FSW machine using specifications from The Welding Institute (TWI) in England. The equipment was built, tooling was made, a joining process procedure was developed in 20 weeks for this application and approximately $1 Million in savings was realized. The FSW fabrication of the units for LLNL was

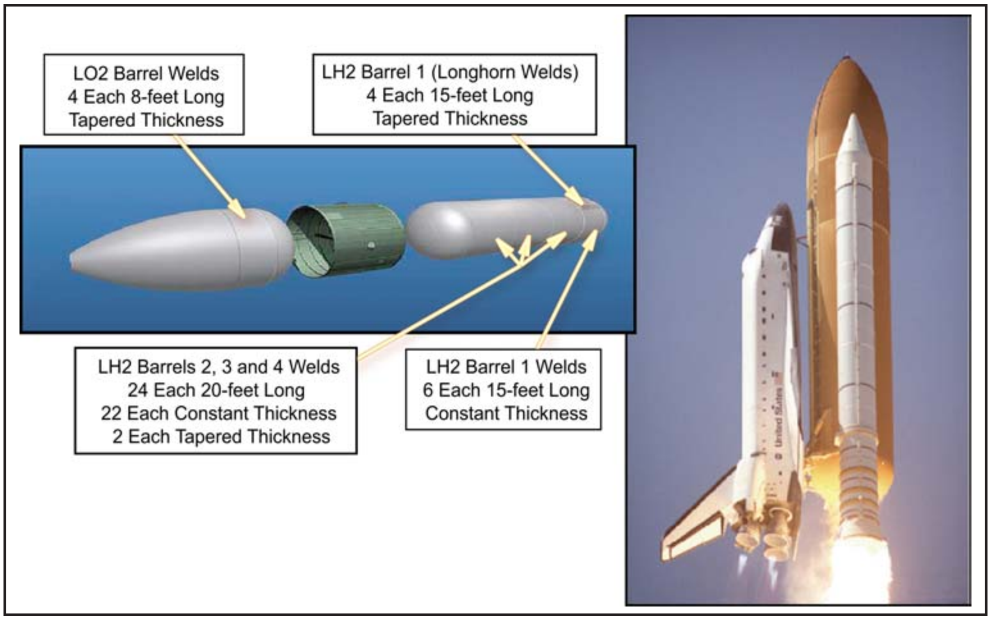

Figure 2-3. Space Shuttle Main Tank and Welds

a technical and financial success. Because of the financial success with this project, GTC shared some of its cost savings with LLNL.

The success of this project with GTC has not gone unnoticed. As a result of its success in making FSW equipment, Lockheed Martin Manned Space Systems contracted GTC for NASA to build three machines to make longitudinal welds in the space shuttle main tank. Two of the three machines made by GTC are among the largest vertical FSW systems produced in the world. Other machines are similar in size, but do not have the retractable pin spindles. Figure 2-3 depicts the longitudinal welds to be friction stir welded for the shuttle's main tank. GTC has received several benefits using FSW technology by acquiring new markets for design and build of FSW equipment (AccuStir™), new job shop business, a new process to take to existing customers, and increased global exposure.

Machining Standards

Using standardized processes and tooling for machining common features on machined parts resulted in less tooling and increased efficiency in the process. Productivity was enhanced while cost and waste was minimized.

Prior to mid to late 2001, General Tool Company (GTC) operated similar to most job shops in the planning and manufacturing of small lot quantities and prototype parts for its customers (i.e., each part was planned from scratch and processed as a unique entity). Numerical control programmers worked with supervisors and machinists to select tooling and cutting parameters on a part-by-part basis. The information gathered was not always captured, documented or shared. Although this approach may have been successful, it was not always conducive to being the most efficient or effective to the hours spent in manufacturing or to the tooling costs. Some of the challenges this approach led to were:

- Tool shortages due to lack of standardized tooling and processes
- Machining process inefficiencies frequently leading to re-programming
- Time wasted to reinvent the wheel with every new job
- Inflated tool crib inventory required to support the system
- Each job subjected to a new learning curve
- Actual cost of the job varying greatly from the estimated cost

GTC's management determined that a shift in mind set from no-two-parts-alike to commonality of features of parts was required in order to remain competitive in today's environment. Large manufacturers had for years successfully used standard shop practices and standardized tooling based on common features rather than individual parts. It was reasoned that this approach should work for a job shop as well. GTC's approach was to divide the universe of milling into eight basic processes: drilling, bore milling, reaming, tapping, boring, profiling, pocketing, and slotting. Standard processing parameters were written, and standardized tooling was selected that would both support each of these processes. The company now had a common tool that engineers, strategists, programmers, and machinists could use to align their thinking. Regardless of its geometry, a part that required profiling would be machined using standardized tooling and methods. Any other part being manufactured that required profiling would follow this same established process. An electronic living document to store the technical organization's lessons learned was created and electronic interface to the company's tooling inventory was also established.

The benefits of this standardization of processes and tooling became instantly identifiable which include:

- Increased efficiency in programming with fewer processes required to learn and store
- Increased efficiency in machining immediately attainable since the machinists are familiar with tooling and techniques
- Reduced tool crib inventory with standardized tooling being used for all like processes
- Minimized special tooling needs

Supply Management Partnership

General Tool Company implemented a tooling and supply management relationship with Dayton Supply and Tool that uses barcode inventory tracking and specialized tool crib software. This partnership allows General Tool Company to reduce its inventory commitment by greater than 50%, provides access to state-of-the-art cutting tools, and infrequent stock outages.

General Tool Company (GTC) requires the highest quality tooling and an appropriate inventory level in order to provide excellence and timely delivery of hardware to customers. GTC's annual expenditure for tooling and supplies is approximately $1 Million in which inflated inventories result in a reduced cash flow and the risk of obsolescence of supplies. In the past, the cost of procuring these supplies was approximately $100,000 per year, and in spite of maintaining a high inventory level ($600,000), frequent supply outages resulted in significant additional expenses for premium freight and order expediting as well as lost production time.

GTC resolved its supply management issues by implementing a tool and supply management agreement with Dayton Supply and Tool (DST) company. DST is GTC's supplier of choice and has first refusal on all GTC tooling, shop supplies, and welding/fabrication consumable orders. GTC is able to keep a minimum stock level and DST guarantees available backup quantities with no more than a 24-hour delay. In addition, GTC and DST are electronically linked through tool crib inventory software, while daily inventory usage and supply levels are closely monitored. When minimum supply levels are reached, a replacement order is initiated through an on-going purchase order. Through this partnership with DST, GTC has reduced its inventory commitment by greater than 50% and has access to state-of-the-art cutting tools and infrequent stock outages.

Facilities

Clean Room Facility

The clean room facility at General Tool Company provides an additional capability that is unusual for a medium-sized, job shop company. The size and material handling capabilities combined with the ability to modify the facility for potential future requirements makes this an exceptional facility.

General Tool Company (GTC) needed an in-house clean area for a project with Lawrence Livermore National Laboratory (LLNL). The requirements for this clean room were unusual due to the sizes and weights of the parts to be put through the cleaning, assembling, and packaging processes. GTC had a Class 10,000 certified clean room facility built specifically for the LLNL project. The clean room facility consists of three rooms: a wet room, a dry room, and an assembly room. These rooms facilitate the final cleaning, drying, and assembling of the parts. The wet room is 16 feet by 18 feet with a 12-foot ceiling, equipped with a 2,000 psi pressure washer, and process water and cleaning solutions available. The dry room is 15 feet by 16 feet and also has a 12-foot ceiling. The wet room is connected to the dry room via sliding glass doors. There is a one-ton monorail crane that spans both rooms to enable the transport of parts between the two rooms. Finally, the assembly room is 32 feet by 34 feet with a 15-foot ceiling, and is equipped with a 2-ton boom crane. This room is also equipped with a ventilation hood, scale, and centrifuge for mixing glue and other products.

Connected to these three rooms are a gown room, staging area (a clean area with high efficiency particulate arrester airflow), and an airlock area to remove the bagged and finished assemblies. The gown room is 8 feet by 12 feet with an 8-foot ceiling, the staging area is 24 feet by 25 feet with a 12-foot ceiling, and the airlock area is 10 feet by 12 feet. Adjacent to the clean rooms, and as a complement to them, are acid and rinse tanks for a cleaning process used prior to moving parts into the clean room. Space is available for additional tanks or processes, if needed for special customer specifications or requirements. The clean rooms operate at less than Class 10,000, and can easily and quickly be converted to Class 1000 or Class 100 depending on the project size and customer needs. The worst readings taken, at rest, during the certification process were 1,673 ppm, for a .5 micron particulate size.

The clean room provides an additional capability that is unusual for a medium-sized, job shop company. The ultra-clean environment with control of airflow, pressure, humidity, temperature, and filtration give GTC an avenue for future business beyond the scope of most, if not all, job shop companies. GTC is willing to bring specialty processes inhouse to support its customer's unique needs and demanding projects.

Fabrication Facility

General Tool Company built a state-of-the-art fabrication facility and developed additional capabilities and certifications to support its customers. This led to new customers as well as expanding business with prior customers.

General Tool Company (GTC) manufactures precision fabricated and machined components. GTC faced a few challenges as the demand for its capabilities increased in volume. The old facility could not handle the new requirements as part sizes increased and part tolerances tightened. The facility was too small and the lifting capacity was limited. Another problem GTC faced was attracting and retaining critical welding and fabricating skills. Due to the physically demanding nature of the work and the high temperatures and humidity conditions experienced during the summer months, the employees faced a very uncomfortable working environment. The facility was congested due to the amount of work and the larger physical size of the parts, and the weight of the parts created safety concerns due to the limited capacity of the existing cranes.

The solution was to build a new, larger, modern, state-of-the-art fabrication facility. By using an employee team, past lessons learned were captured to incorporate into the new facility's design. An air conditioned environment was required for employee comfort and necessary for holding tighter tolerances. The air conditioning system was designed to carry the welding smoke away from the operators. The cleaner air environment also contributed to higher quality welds. The gas supplies were piped throughout the facility to eliminate gas bottles on the floor and to keep the consistency of its supply.

GTC's new facility is 32,000 square feet with two 20-ton overhead cranes, two 10-ton overhead cranes, two 3-ton walking jib cranes with the capability to add two more, and many stationary jib booms. Every upright beam can support a stationary jib boom. Flatbed semi-truck trailers can be backed into the facility and unloaded at the receiving and material storage area. The employees laid out the facility to enhance material flow. The floor itself was constructed with embedded, grounded steel I-beams that are coplanar within .125 inch every 20 feet and no more than .375 inch over the entire building length, creating the capability to use the floor itself for a precise fit-up table for large assemblies. The grit blast capacity was also significantly increased, and the chamber was designed such that the blast media is collected and pumped back outside for reuse which created a cleaner and safer environment for the employees.

During the facility's planning, it was recognized that the capabilities needed to be broadened in other ways. Accreditation was obtained from National Aerospace and Defense Contractors Accreditation Program (NADCAP) for welding, brazing, and nondestructive testing (NDT). Three employees are certified as weld inspectors, and GTC hired an additional weld engineer to perform these projects. GTC became a member of the Edison Welding Institute and is linked to The Weld Institute in the United Kingdom. GTC can now perform many projects including Level III NDT in radiography, ultrasonics, penetrants, and magnetic particle inspections. They also have full capabilities and certifications in place for aluminum, steel, and exotic materials.

The new facility can generate an excess of 100,000 direct labor hours per year. Now the employee turnover rate is near zero since they have a safe working and comfortable environment. GTC's lost time accidents have also been zero for the last 24 months. With this implementation, new customers are attracted to the new facility and to GTC's expanded capabilities and certifications.

Non-Conventional Inspection Methods

General Tool Company has demonstrated that non-conventional inspection methods can be efficient and cost effective for the small volume production of large parts with intermediate tolerance requirements. In many cases, the cost savings can approach 20% relative to conventional techniques such as functional gages, standard measurement instruments, and coordinate measuring machines. In some cases, the combination of part size, complexity and tolerance factors make non-conventional inspection techniques the only practical approach.

General Tool Company (GTC) is often chosen to supply one-of-a-kind, large parts with unique geometry. The tolerance requirement for these work pieces is typically around +/- 0.015 of an inch. This manufacturing environment requires efficient, economical, and short turn-around dimensional measurements for both process control and final product acceptance. In addition, while the measurements must be accurate, it is often inappropriate to move the parts to a remote station for in-process inspection operations due to the difficulty in realigning the work piece on the machine tool. In other cases, the lack of rigidity of the freestanding work piece makes off-machine certification a difficult and expensive challenge.

Figure 2-4. Computerized Arm

GTC developed non-conventional inspection methods that have proven to be particularly well suited to the intermediate-tolerance, cost-competitive, short delivery cycle job shop environment. These inspection methods include the use of a Laser Tracker; an articulated computerized, programmable inspection arm; and out-of-cycle dimensional measurements. The Laser Tracker is an optical inspection device that measures the position of a target element that is placed at various target points on a work piece. It provides dimensional inspection information on very large parts with measurement accuracy in the range of a few thousandths of an inch (in a relatively well-controlled environment) at a cost far below that of conventional large, multi-axis machine tools. In addition, the gage works directly with computer aided design files as well as supports other activities, such as layout work and assembly operations. The computerized inspection arm offers a flexible, efficient means of collecting dimensional inspection information on surfaces that can be accessed via a manually positioned articulating arm. The operator moves a tip located on the end of the arm to the desired inspection point of the work piece and presses a button to communicate with the system software. While this system's accuracy is also limited to a few thousandths of an inch, it provides a great deal of flexibility since it can be easily mounted on surfaces such as a machine component (for on-machine measurements) or a surface plate for general use (see Figure 2-4). A similar out-of-cycle inspection approach is to mount a probe or other indicator on the machine tool holder and use it to measure the relative location between the work piece surface and an on-machine dimensional reference. This technique depends on the use of a machine-mounted master artifact that provides a positional reference for the measurement system and a machine calibration procedure that assures that the machine positional errors in the measurement zone are significantly smaller than the required tolerances.

Non-conventional inspection methods are efficient and cost effective for the small volume production of large parts with intermediate tolerance requirements. The methods provide an accurate means of inspecting without the expense of special gages or the time required of conventional methods.

Roof Mist Cooling

General Tool Company installed a roof misting evaporative cooling system to provide additional cooling for the machine shop. Compared to the cost of conventional air conditioning systems, the installation costs for the system are less than 20%, and the annual operating and maintenance costs are less than 10%.

The air conditioning for General Tool Company's (GTC's) machine shop became inadequate to provide the cooling necessary for the added heat load from new equipment. Additional airflow to facilitate the clean shop air was also needed. The conventional air conditioning equipment would require an air handler and a 100-ton condenser for the 60,000 square foot machine shop, which would have cost $130,000 and required $28,000 per year in operating and maintenance costs.

An investigation into alternative solutions showed a system utilizing roof mist sprinkling to provide evaporative cooling of the roof and ceiling zone of the plant to reduce heat build-up and the radiant heat load of the roof. The roof misting system includes a micro controller and sensors to monitor roof surface temperatures by zones. This enables the controller to minimally mist water on the roof surface independently as the roof temperature rises. The materials and installation cost for the 60,000 square foot facility was less than $25,000 to provide the equivalent of 100 tons of cooling on a 90-degree day.

GTC installed a roof misting evaporative cooling system to provide additional cooling for the machine shop. During the system's six seasons of operation, the annual operating and maintenance costs have averaged less than $2,500. The system also provides the additional benefit of extending the life of the roof surface by keeping it at a lower temperature. The heat load has been reduced sufficiently for the original air conditioning system to cool the shop floor adequately on the hottest days. The system has provided excellent results and has only required minimal maintenance.

Management

CNC Strategist: Improving Throughput in CNC Programming

General Tool Company's implementation of the Computer Numerical Control Strategist position resulted in a significant drop in the amount of reprogramming and also allowed the programmers to spend a larger part of their time developing expertise in advanced Computer Numerical Control programming technologies.

General Tool Company (GTC) has 32 Computer Numerical Control (CNC) machine tools that are supported by four part programmers. These highly trained personnel use software from Unigraphics and Surfware to supply part programs for lathes, boring mills, and machining centers. In addition, these programmers have historically supported tooling selection and procurement as well as inventory management services for CNC operations.

As GTC's CNC workload grew, it became increasingly difficult to efficiently provide the needed part programs. GTC discovered that as much as 60% of the programmers' time was spent away from their workstations resolving peripheral issues such as tooling selection and resolving technical issues on the shop floor. These individuals were highly trained in the use of CNC software, yet they spent much of their time performing secondary tasks that resulted in significant bottlenecks in the programming department that could not be effectively resolved, except with the addition of more programmers.

GTC's resolution of this problem was to further divide the labor required to move jobs from the manufacturing engineers to the part programmers by creating an intermediary called a CNC Strategist. Under this scenario, the manufacturing engineers spend more time developing the processes and performing project management functions, the CNC Strategist addresses all tooling-related issues and process problems, and the programmers' focus on the production of high quality CNC code. The implementation of the CNC Strategist position resulted in a significant drop in the amount of reprogramming and also allowed the programmers to spend a larger part of their time developing expertise in advanced CNC programming technologies.

Certification to Program Standards

The National Aerospace and Defense Contractors Accreditation Program certification for nondestructive testing, welding, and brazing requires both documented procedures and process control. General Tool Company found that many of the requirements of the certification were already in place as a result of its efforts in obtaining ISO 9001 and AS 9000 certifications and has resulted in cost savings for the company.

General Tool Company (GTC) had previously completed certification to ISO 9001 and AS 9000. The decision to become certified to the National Aerospace and Defense Contractors Accreditation Program (NADCAP) in the areas of nondestructive testing (NDT), welding, and brazing was based on customer requirements. Through NADCAP, the Performance Review Institute accredits subcontractors and suppliers to aerospace and defense industry consensus standards.

GTC found that many of the requirements of NADCAP were already in place as a result of its efforts in obtaining ISO 9001 and AS 9000 certifications. However, certification for NADCAP introduced tighter process control for NDT as well as some improvements to process documentation. For example, an initial check of the dye penetrant batch on a daily basis replaced weekly checks, which limits any problems to just one day's testing. Also it reduced costs as the penetrant batch was previously replaced at the end of each week; yet it is now used longer because tests indicated weekly replacement was unnecessary. A control/tracking matrix has now been implemented to track the calibration cycles of NDT equipment.

Another improvement from obtaining the NADCAP certification was realized in operation procedures. Operation procedures were the challenge for welding and brazing, due to few being in place and the variety of specifications and standards that had to be met. GTC brought in an outside expert to assist in writing and implementing the tighter process controls. GTC implemented new procedures and process documents for increased control of each NDT method. Standardizing practices for the assemblies that GTC builds on a repetitive basis reduces the possibility of unforeseen circumstances later in the manufacturing process.

There have been several benefits as a direct result of these improvements. GTC is now using approximately one less barrel of dye penetrant per year, a savings of approximately $1,500 per year. The tracking matrix allowed for increases in the calibration cycles, providing further cost savings. As a direct result of the standard practices being written for welding and assembly operations, the machining time for Penetration Housings has been reduced and overall efficiencies have improved (see Figure 2-5). The machinist noticed that the machining times for the housings were inconsistent; yet one welder's product time has been 30 minutes less than the other welders. Further investigation found that the welder used a slightly different sequence for assembling and welding the part. The sequence used has been documented and is now the standard procedure, and has proven to increase the efficiency with which this part is built. GTC found that the reduction in time or elimination of source audits proves to be the biggest advantage for the NADCAP certification. This certification enhances quality all around. GTC not only meets the high standards of NADCAP, but also helps set them.

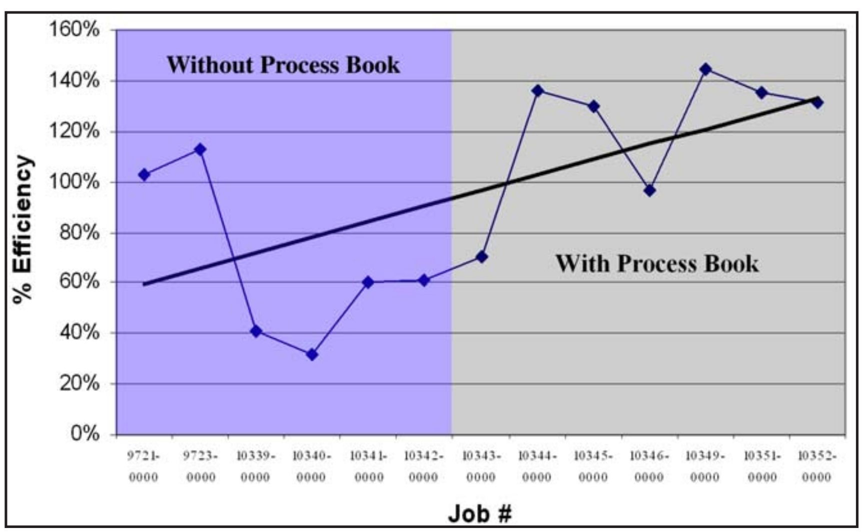

Figure 2-5. Machining Efficiency of Penetration Housings

Safety Program

General Tool Company developed an effective safety program that improved safety and reduced related costs. Primarily, the company has involved the entire work force in the safety program.

General Tool Company (GTC) implemented a safety program based on continuous improvement. The increasing costs of lost productivity, accidents, workers' compensation insurance premiums, and regulatory compliance caused GTC to review its safety program. The intent of the program is to improve safety, and reduce costs at the same time. After a thorough review and consulting with the State Bureau of Workers' Compensation, GTC decided that the best approach was the formation of a safety committee to oversee the development and implementation of a revised safety program that maintained regulatory compliance, while enhancing and improving all safety disciplines. The program resulted in an updated safety manual, increased safety training, and increased supervisor safety interventions.

GTC requires all employees, management as well as shop personnel, to attend safety training and comply with all the company's safety requirements, while new employees are indoctrinated prior to starting work. Safety issues are discussed at most of the monthly employee meetings. Additionally, all employees are encouraged to make suggestions and stop any safety violation they observe. A reward system has also been implemented, which encourages employees to make safety inputs. When there were a few close calls after September 11, 2001, GTC requested a safety audit. The review of the company's facilities indicated only a few minor discrepancies between requirements and practices.

The company instills in its employees the understanding that they are the first line of defense for safety. This safety-first attitude has resulted in dramatic improvements and savings. Accidents and injuries have been reduced by 50%; there have been no lost time accidents in over two years; employee involvement and attitude have increased; and GTC has saved over $827,000 in Bureau of Workers' Compensation Insurance premiums the past five years. GTC was also one of only twelve companies in Ohio to receive the Governor's Award for Excellence in Safety. After two years, the initial policies and programs are in place, the training is ongoing, and program improvement is progressing.

Weld Operator Education and Training

The welding engineering staff at General Tool Company created a training and education curricula to enhance the knowledge base, understanding, and skill level of the present manual weld operator staff to improve its quality. The curricula brought forth encouraged constructive dialogue between the engineering staff and weld operators to improve the efficiency of weld operations in excess of 30%.

Welding operators were hired into General Tool Company (GTC) not having the requisite experience to perform effectively in the company, due in part to the declining work force of highly skilled manual welding operators in the United States. Weld operators entering the work force have minimal knowledge of welding. The lack of fundamental knowledge in blueprint reading and procedural specifications related to welding has occasionally led to unnecessary rework and/or scrap, thus reducing the company's productivity, quality, and efficiency.

GTC's desire is to hire highly skilled welders, but out of necessity has acquired low skilled, yet highly motivated individuals to train as qualified welders. GTC's definition of a qualified welder is an individual that can produce a radiographic-quality weld, free of unacceptable indications. GTC also desires that the individual understand other aspects related to the job that include:

- Producing the correct welded joint as specified by the blueprint (i.e., weld symbols or visual inspection requirements)
- Understanding and following standard welding procedural specifications
- Recognizing the difference in a quality weldment verses an unacceptable weldment by understanding typical weld defects and causes

To remedy the issue of an unskilled welding work force within the company, GTC created a training and education program to provide core competencies and enhanced knowledge to increase the performance level and understanding of its welding personnel. The welding engineering staff created training modules encompassing General Shop Practices, Standard Weld Symbols for Blueprint Reading, and Visual Inspection.

The General Shop Practices module addresses procedural specifications by defining the weld performance qualification record and the welding procedure specification. This training provides a standardized tool for welding personnel to identify the proper welding techniques, welding parameters, and requisite welding codes necessary to produce quality weldments. The second module instructs the welder in the proper interpretation of standardized welding symbols as defined by the American Welding Society. These symbols are placed on blueprints to instruct the welder as well as the designer to the type of welding process to be utilized, weld joint location, weld joint preparation, weld size/contour, and the weld filler alloy employed. With the knowledge of symbols, PQRs, and WPSs, weld personnel are able to produce the required weldments meeting the design intent of the weld-fabricated assembly. The third module, Visual Inspection, aids welding personnel by identifying important information about conformity to a specification. Different types of weld discontinuities are discussed and identified by sketches and/or photographs. Possible causes of these discontinuities are also discussed.

The training and education modules brought forth by GTC have been implemented since March 2002. As a result of training, the present weld work force with varying years of experience have obtained an enhanced understanding of welding. The entire welding staff has been brought to the same level of knowledge and understanding. This achieved effective communication between the engineering staff and weld operators to promote ideas on making weld joints better for improved quality and productivity. Since the initial training classes, the welders have been more attentive when reading weld symbols and have brought attention to inappropriate weld symbols specified by design engineers.

Important to the business side of the company, the overall efficiency of the welders has increased more than 30%. Efficiency has been defined as the percentage of actual time to complete the weld operation compared to the routed time standards. Figure 2-6 depicts the change in weld operator efficiency over the first five months since the training and education modules have been implemented. The level of efficiency began at 45% and has climbed to 70% during this short period. GTC proposes to use the created training and education modules when hiring new welding operators.

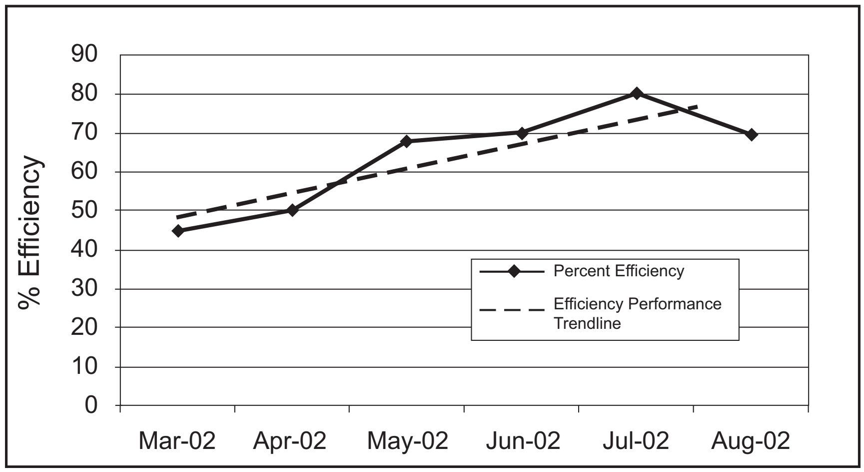

Figure 2-6. Weld Operator Efficiency

Section 3
Information

Production

Composites Machining

General Tool Company has made great strides in the machining of non-metallic or composite materials. Through controlled experimentation of cutting speeds and feeds, and intensive investigation of tool types and geometry, the company has been able to develop affordable machine processes and products for its customers.

The machining of composite materials, both conventional “lay ups” and filament wound materials, presents unique challenges to the manufacturing community. The composites exhibit different machining characteristics than common metal alloys normally encountered in manufacturing. They respond differently to conventional machining processes and, due to their abrasive nature, greatly reduce the useful life of standard cutting tools.

General Tool Company (GTC) has been able to overcome some of the obstacles of machining composites. Working together with different cutting tool manufacturers and through much experimentation, GTC has been able to develop standards and processes that enable it to successfully machine composite materials for its customers. Some of the key solutions for success include high spindle speeds, light or shallow depth of cuts, and aggressive feed rates approaching 140 inches per minute in some cases. Part geometry and holding fixture rigidity dictate the correct speeds and feeds.

A real key to successfully machine these composites at an affordable cost lies in the cutting tools used. Several attempts with special carbide and high speed steel tools have produced varied results in both tool life and varying degrees of delamination of the composite structure. One of the most promising cutting tools used for drilling is an eight-faceted, thinned web, diamond tipped carbide drill. This tool enabled GTC to reduce cycle times and greatly increase tool life in small hole drilling. Milling of composites is generally accomplished with diamond mesh end mills. This operation is more of a grinding operation in lieu of milling.

Through ongoing investigation of tool types and tool geometry, GTC has found that more improvements are attainable. Continued experimentation with speeds and feeds will find the best way to produce quality parts on a consistent basis. GTC has made process improvements and changes in tool specifications, which have resulted in reduced cycle times and improved tool life.

In the Field Defects

General Tool Company has taken a proactive approach to solving an end user satisfaction issue and is now using similar approaches to preclude issues with new products in the field. As a result, the end users are extremely satisfied with the product.

The Navy's Generator Set Program at General Tool Company (GTC) had some problems when deployed in the field. The system met all of the required specifications, but there were many things that had not been specified in the design that caused difficulties during deployment (e.g., access panels that could not be removed when the generator set was installed aboard the ship; and many instances when an inspection for preventive maintenance required the removal of several pieces of the equipment to gain access). When failures were encountered, typically additional failures were reported that were caused by the repair of the first failure. The equipment met the contractual obligation, but the end user was not satisfied with the results.

GTC could have ignored the dissatisfaction since all requirements of the contract had been fulfilled, but instead took a proactive approach to satisfy the end user. The end user and field personnel were consulted to determine all of the shortcomings in their environment. All requirements for inspections were defined, the onboard spare parts were reviewed, and the repair plans were reviewed for whether the repair would be performed underway or in port. The end users provided the input on accessibility issues for preventive maintenance and repair of the system.

The next step in the process was to analyze the changes needed to facilitate the end users' desires.

Many of the changes would add additional costs to the product, but in several instances the changes actually resulted in decreased costs. The final result was that GTC was able to absorb the difference in costs and redesigned the system to incorporate the desired changes. In one instance, the supplier of a part would not change the design to accommodate the differences, which resulted in GTC bringing on a new supplier of that part.

The new generator set design has had 30% fewer reported problems and a corresponding increase in the mean time between failure. The system is not being damaged during repair or inspection procedures, and the end user is now extremely happy with the product. GTC is applying the philosophy learned on this project to other projects. The success of each product in the field can be attributed to the up-front involvement of GTC.

Management

Customer Feedback

General Tool Company has a sincere desire to know how potential customers want it to market its services to them. Through the use of General Tool Company's customer satisfaction survey process and the statistical analysis of the returned customer surveys, the company is able to gauge the health and effectiveness of its efforts.

Compliance with ISO 9001-2000 Standards requires a Quality Management System to gather data about customer satisfaction and report to management so they may take any necessary corrective action. Prior to early 2000, General Tool Company (GTC) did not have a formal methodology to solicit feedback from its customers in a consistent manner. Additionally, no formal reporting system to management existed that collected any feedback that the company received. Customers would often make comments, both positive and negative, to people they normally interfaced with at GTC. These comments were communicated only by word-of-mouth to parties that were directly involved with that particular customer.

In an effort to become compliant with the ISO requirement and better understand customers' needs and degrees of satisfaction with GTC, the company took the steps required to develop and implement an effective feedback system. GTC hired an outside consultant who took an off-the-shelf package called "Statpac" and customized it to meet the company's needs. This customized package enabled GTC to interface with its own database of closed sales orders and display them in the customer feedback system. The process owner is able to select the customer point of contact for their related jobs and initiate the survey process. The survey process is web based, and only requires approximately ten minutes of the customer's time to complete. GTC management then statistically analyzes the gathered data for trends needing improvement. This system provides GTC management with customer satisfaction information that directly impacts areas its customers think need the most improvement.

Intranet Platform

General Tool Company is pursuing an activity to improve its internal efficiencies by developing an intranet platform for enhanced information management. The platform will house data essential for employee awareness as well as instructions for manufacturing and equipment maintenance.

The intranet, just like its counterpart the Internet, is gaining more acceptance as a business tool for enhancing the effectiveness of a company's performance by managing company information/data for improved internal communication. As a tool, the intranet is capable of providing information to the user in a convenient and consistent manner from a central location within the confines of a company's infrastructure.

Typically, General Tool Company (GTC) finds itself in situations where there is a lack of understanding across departments about widely available information, resources, and tools. Along with the lack of understanding of the available data, the information is fragmented and located in various areas within the company. This requires the employee to search from one location to another to get full information detail that is needed, and each user is wasting time developing different forms for the same purpose.

As an effort to make information within GTC universally available to its employees, the information technology staff is undertaking a task to develop an intranet to provide easy access to internal documents, commonly used templates, shared information, and other resources. Development activities began by compiling a list of items from input within GTC to be published on the intranet. The initial list of items includes:

- Human Resource activities and benefits with links to insurance and 401K savings information
- Interdepartmental workload reports
- Links to machine specifications and maintenance schedules
- Tooling inventory and calibration schedules
- Quality information (e.g., manuals and ISO specifications)
- Information System's tips and frequently asked questions
- Preferred vendor lists
- Monthly finance information
- Available resources list and forms
- Published processes and procedures
- Sales activity

Once GTC completes the development of the intranet and activates the system, the company anticipates a more cohesive work force resulting in saved time, increased efficiency, and fewer errors due to better data management.

Performance Management and Review System

The Performance Management and Review System at General Tool Company clearly sets forth the needs and expectations of both the company and the employees. Furthermore, it provides a meaningful measurement of performance to those needs and expectations.

In late 2001, General Tool Company (GTC) began the difficult process of formalizing and instituting a performance management and review system that reflected commitment to its customers and employees. Work force development had long been one of the strengths deemed critical to the company's strategic plan success factors. Prior to this effort, the employee performance plan in place hindered GTC's ability to focus on the needs of the employee as well as the company. The old system of job descriptions, goal setting, and performance appraisals was antiquated and insufficient to support performance management and measurement needs. Clear definition and communication of performance expectations were inconsistent and, in many cases, non-existent. Finally, the old system did not clearly define ownership and accountability for performance.

Earlier in 2001, GTC management created a cross-functional team of managers and employees with the mandate to create a system that would meet the objectives and requirements of the company. Some of the objectives were to rewrite all job descriptions to include minimum levels of skill, education, experience, and knowledge; to define key result areas of deliverable expectations for each person in the company; and to develop a new annual performance management and process for annual appraisals that included self appraisal, goal setting, human resource intervention, and mandatory management review.

The team developed a system that will help the management and employees attain the company's original objective. The new plan provides for individual performance levels that are agreed upon yearly between supervisors and the individual employees. Expectations of both management and the work force are defined and measured, career paths are clearly identified for each person in the company, and competence across the work force is constantly measured and raised. GTC has found that accountability and ownership for results is widely accepted by all employees. The philosophy of GTC in continuous improvement is defined as “What we do, not what we say.” The company's performance appraisal and measurement system reinforces that philosophy.

Appendix A
Table of Acronyms

ACRONYM	DEFINITION
CNC	Computer Numerical Control
DST	Dayton Supply and Tool
FSW	Friction Stir Welding
GE	General Electric
GTC	General Tool Company
LLNL	Lawrence Livermore National Labs
NADCAP	National Aerospace and Defense Contractors Accreditation Program
NC	Numerical Control
NDT	Nondestructive Testing
TWI	The Welding Institute

Appendix B
BMP Survey Team

Team Member	Activity	Function
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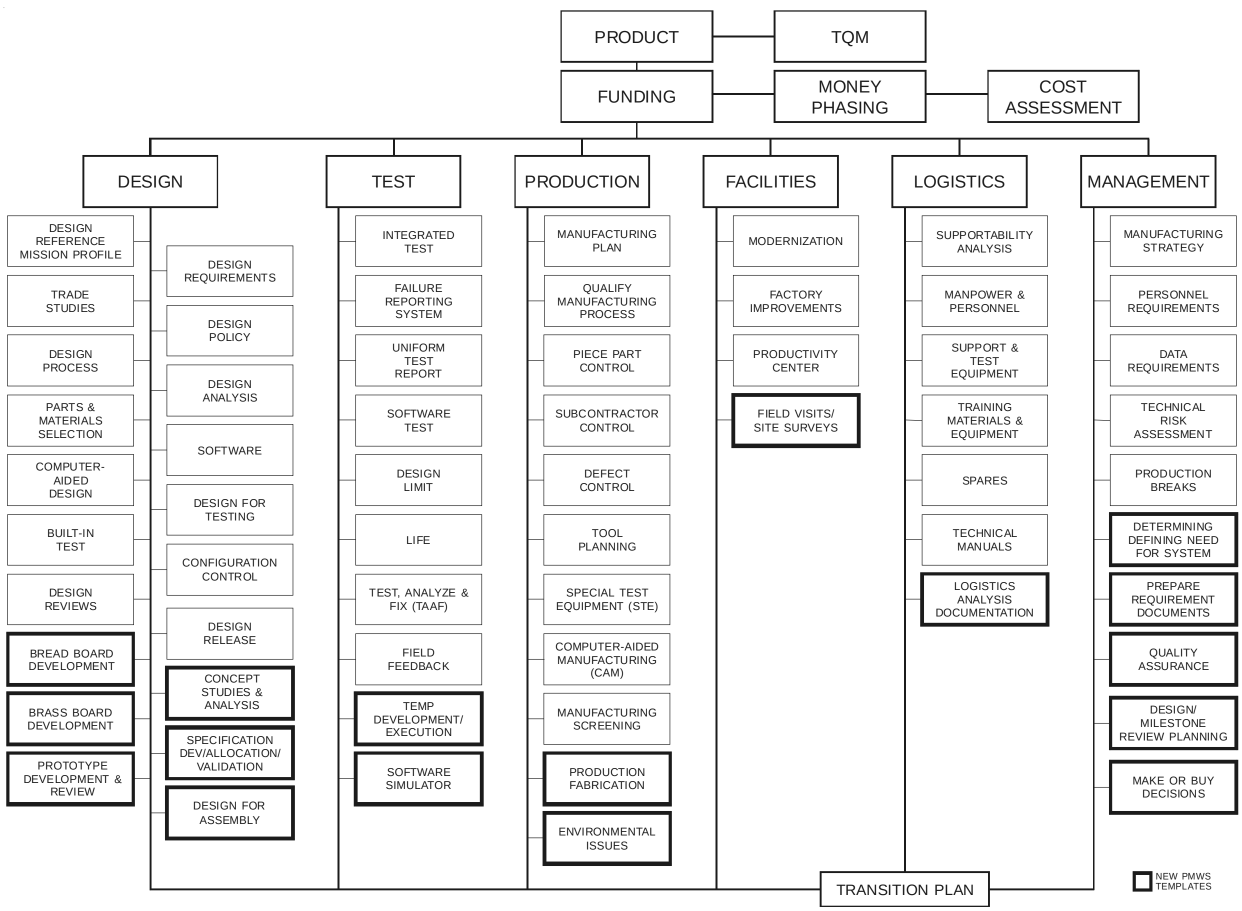
Appendix C

Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, *Transition from Development to Production* document. This publication defines the proper tools—or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing it as an *industrial* process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

"CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION"



Appendix D

The Program Manager's WorkStation

The Program Manager's WorkStation (**PMWS**) is an electronic suite of tools designed to provide timely acquisition and engineering information to the user. The main components of PMWS are KnowHow; the Technical Risk Identification and Mitigation System (TRIMS); and the BMP Database. These tools complement one another and provide users with the *knowledge*, *insight*, and *experience* to make informed decisions through all phases of product development, production, and beyond.

KnowHow provides knowledge as an electronic library of technical reference handbooks, guidelines, and acquisition publications which covers a variety of engineering topics including the DOD 5000 series. The electronic collection consists of expert systems and simple digital books. In expert systems, KnowHow prompts the user to answer a series of questions to determine where the user is within a program's development. Recommendations are provided based on the book being used. In simple digital books, KnowHow leads the user through the process via an electronic table of contents to determine which books in the library will be the most helpful. The program also features a fuzzy logic text search capability so users can locate specific information by typing in keywords. KnowHow can reduce document search times by up to 95%.

TRIMS provides insight as a knowledge based tool that manages technical risk rather than cost and schedule. Cost and schedule overruns are downstream indicators of technical problems. Programs generally have had process problems long before the technical problem is identified. To avoid this progression, TRIMS operates as a process-oriented tool based on a solid Systems Engineering approach. Process analysis and monitoring provide the earliest possible indication of potential problems. Early identification provides the time necessary to apply corrective actions, thereby preventing problems and mitigating their impact. TRIMS is extremely user-friendly and tailorable. This tool identifies areas of risk; tracks program goals and responsibilities; and can generate a variety of reports to meet the user's needs.

The **BMP Database** provides experience as a unique, one-of-a-kind resource. This database contains more than 2,500 best practices that have been verified and documented by an independent team of experts during BMP surveys. BMP publishes its findings in survey reports and provides the user with basic background, process descriptions, metrics and lessons learned, and a Point of Contact for further information. The BMP Database features a searching capability so users can locate specific topics by typing in keywords. Users can either view the results on screen or print them as individual abstracts, a single report, or a series of reports. The database can also be downloaded, run on-line, or purchased on CD-ROM from the BMP Center of Excellence. The BMP Database continues to grow as new surveys are completed. Additionally, the database is reviewed every other year by a BMP core team of experts to ensure the information remains current.

For additional information on PMWS, please contact the Help Desk at (301) 403-8179, or visit the BMP web site at http://www.bmpcoe.org.

Appendix E

Best Manufacturing Practices Satellite Centers

There are currently ten Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP Program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; and train regional personnel in the use of BMP resources.

The ten BMP satellite centers include:

California

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Code QA-21, P.O. Box 5000
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FAX: (703) 805-3721
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Appendix F

Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Technology Program has established Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and the Navy industrial facilities and laboratories. These consortium-structured COEs serve as corporate residences of expertise in particular technological areas. The following list provides a description and point of contact for each COE.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and share best manufacturing and business practices being used throughout government, industry, and academia. The BMPCOE was established by the Office of Naval Research's BMP Program, the Department of Commerce, and the University of Maryland at College Park. By improving the use of existing technology, promoting the introduction of improved technologies, and providing non-competitive means to address common problems, the BMPCOE has become a significant factor to counter foreign competition.

Point of Contact:
Anne Marie T. SuPrise, Ph.D.
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
Phone: (301) 403-8100
FAX: (301) 403-8180
E-mail: annemari@bmpcoe.org

Institute for Manufacturing and Sustainment Technologies

The Institute for Manufacturing and Sustainment Technologies (iMAST) is located at the Pennsylvania State University's Applied Research Laboratory. iMAST's primary objective is to address challenges relative to Navy and Marine Corps weapon system platforms in the areas of mechanical drive transmission technologies, materials processing technologies, laser processing technologies, advanced composites technologies, and repair technologies.

Point of Contact:
Mr. Robert Cook
Institute for Manufacturing and Sustainment Technologies
APL Penn State
P.O. Box 30
State College, PA 16804-0030
Phone: (814) 863-3880
FAX: (814) 863-1183
E-mail: rbc5@psu.edu

SCRA Composites Manufacturing Technology Center

The Composites Manufacturing Technology Center (CMTC) is a Center of Excellence for the Navy's Composites Manufacturing Technology Program. The South Carolina Research Authority (SCRA) operates the CMTC and The Composites Consortium (TCC) serves as the technology resource. The TCC has strong, in-depth knowledge and experience in composites manufacturing technology. The SCRA/CMTC provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors.

Point of Contact:
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FAX: (864) 656-4435
E-mail: watson@scra.org

Electronics Manufacturing Productivity Facility

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of government, industry, and academic participants led by the American Competitiveness Institute under a Cooperative Agreement with the Navy.

Point of Contact:
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Electronics Manufacturing Productivity Facility
One International Plaza, Suite 600
Philadelphia, PA 19113
Phone: (610) 362-1200
FAX: (610) 362-1294
E-mail: criswell@aci-corp.org

Electro-Optics Center

The Electro-Optics Center (EOC) is a national consortium of electro-optics industrial companies, universities, and government research centers that share their electro-optics expertise and capabilities through project teams focused on Navy requirements. Through its capability for national electronic communication and rapid reaction and response, the EOC can address issues of immediate concern to the Navy Systems Commands. The EOC is managed by the Pennsylvania State University's Applied Research Laboratory.

Point of Contact:
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Kittanning, PA 16201
Phone: (724) 545-9700
FAX: (724) 545-9797
E-mail: kharris@psu.edu

Navy Joining Center

The Navy Joining Center (NJC) provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues. The NJC is operated by the Edison Welding Institute.

Point of Contact:
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1250 Arthur E. Adams Drive
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FAX: (614) 688-5001
E-mail: dave_edmonds@ewi.org

National Center for Excellence in Metalworking Technology

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. Operated by the Concurrent Technologies Corporation, the NCEMT helps the Navy and defense contractors improve manufacturing productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:
Mr. Richard Henry
National Center for Excellence in Metalworking Technology
c/o Concurrent Technologies Corporation
100 CTC Drive
Johnstown, PA 15904-3374
Phone: (814) 269-2532
FAX: (814) 269-2501
E-mail: henry@ctc.com

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality, and safe energetics. The EMTC's focus is on technologies to reduce manufacturing costs, improve product quality and reliability, and develop environmentally benign manufacturing processes. The EMTC is located at the Indian Head Division of the Naval Surface Warfare Center.

Point of Contact:
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Indian Head Division
Naval Surface Warfare Center
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Phone: (301) 744-4417
DSN: 354-4417
FAX: (301) 744-4187
E-mail: broughja@ih.navy.mil

Gulf Coast Region Maritime Technology Center

The Gulf Coast Region Maritime Technology Center (GCRMTC) fosters competition in shipbuilding technology through cooperation with the U.S. Navy, representatives of the maritime industries, and various academic and private research centers throughout the country. Located at the University of New Orleans, the GCRMTC focuses on improving design and production technologies for shipbuilding, reducing material costs, reducing total ownership costs, providing education and training, and improving environmental engineering and management.

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Gulf Coast Region Maritime Technology Center
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College of Engineering
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Appendix G
Completed Surveys

As of this publication, 130 surveys have been conducted and published by BMP at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMP web site. Requests for copies of recent survey reports or inquiries regarding BMP may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 400
College Park, MD 20740
Attn: Anne Marie T. SuPrise, Ph.D., Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
annemari@bmpcoe.org

1985	Litton Guidance & Control Systems Division - Woodland Hills, CA
1986	Honeywell, Incorporated Undersea Systems Division - Hopkins, MN (now Alliant TechSystems, Inc.) Texas Instruments Defense Systems & Electronics Group - Lewisville, TX General Dynamics Pomona Division - Pomona, CA Harris Corporation Government Support Systems Division - Syosset, NY IBM Corporation Federal Systems Division - Owego, NY Control Data Corporation Government Systems Division - Minneapolis, MN
1987	Hughes Aircraft Company Radar Systems Group - Los Angeles, CA ITT Avionics Division - Clifton, NJ Rockwell International Corporation Collins Defense Communications - Cedar Rapids, IA UNISYS Computer Systems Division - St. Paul, MN
1988	Motorola Government Electronics Group - Scottsdale, AZ General Dynamics Fort Worth Division - Fort Worth, TX Texas Instruments Defense Systems & Electronics Group - Dallas, TX Hughes Aircraft Company Missile Systems Group - Tucson, AZ Bell Helicopter Textron, Inc. - Fort Worth, TX Litton Data Systems Division - Van Nuys, CA GTE C^3 Systems Sector - Needham Heights, MA
1989	McDonnell-Douglas Corporation McDonnell Aircraft Company - St. Louis, MO Northrop Corporation Aircraft Division - Hawthorne, CA Litton Applied Technology Division - San Jose, CA Litton Amecom Division - College Park, MD Standard Industries - LaMirada, CA (now SI Manufacturing) Engineered Circuit Research, Incorporated - Milpitas, CA Teledyne Industries Incorporated Electronics Division - Newbury Park, CA Lockheed Aeronautical Systems Company - Marietta, GA Lockheed Missile Systems Division - Sunnyvale, CA (now Lockheed Martin Missiles and Space) Westinghouse Electronic Systems Group - Baltimore, MD (now Northrop Grumman Corporation) General Electric Naval & Drive Turbine Systems - Fitchburg, MA Rockwell Autonetics Electronics Systems - Anaheim, CA (now Boeing North American A&MSD) TRICOR Systems, Incorporated - Elgin, IL
1990	Hughes Aircraft Company Ground Systems Group - Fullerton, CA TRW Military Electronics and Avionics Division - San Diego, CA MechTronics of Arizona, Inc. - Phoenix, AZ Boeing Aerospace & Electronics - Corinth, TX Technology Matrix Consortium - Traverse City, MI Textron Lycoming - Stratford, CT

1991	*Resurvey of Litton Guidance & Control Systems Division* - Woodland Hills, CA Norden Systems, Inc. - Norwalk, CT (now Northrop Grumman Norden Systems) Naval Avionics Center - Indianapolis, IN United Electric Controls - Watertown, MA Kurt Manufacturing Co. - Minneapolis, MN MagneTek Defense Systems - Anaheim, CA (now Power Paragon, Inc.) Raytheon Missile Systems Division - Andover, MA AT&T Federal Systems Advanced Technologies and AT&T Bell Laboratories - Greensboro, NC and Whippany, NJ *Resurvey of Texas Instruments Defense Systems & Electronics Group* - Lewisville, TX
1992	Tandem Computers - Cupertino, CA Charleston Naval Shipyard - Charleston, SC Conax Florida Corporation - St. Petersburg, FL Texas Instruments Semiconductor Group Military Products - Midland, TX Hewlett-Packard Palo Alto Fabrication Center - Palo Alto, CA Watervliet U.S. Army Arsenal - Watervliet, NY Digital Equipment Company Enclosures Business - Westfield, MA and Maynard, MA Computing Devices International - Minneapolis, MN (now General Dynamics Information Systems) *(Resurvey of Control Data Corporation Government Systems Division)* Naval Aviation Depot Naval Air Station - Pensacola, FL
1993	NASA Marshall Space Flight Center - Huntsville, AL Naval Aviation Depot Naval Air Station - Jacksonville, FL Department of Energy Oak Ridge Facilities (Operated by Martin Marietta Energy Systems, Inc.) - Oak Ridge, TN McDonnell Douglas Aerospace - Huntington Beach, CA (now Boeing Space Systems) Crane Division Naval Surface Warfare Center - Crane, IN and Louisville, KY Philadelphia Naval Shipyard - Philadelphia, PA R. J. Reynolds Tobacco Company - Winston-Salem, NC Crystal Gateway Marriott Hotel - Arlington, VA Hamilton Standard Electronic Manufacturing Facility - Farmington, CT (now Hamilton Sundstrand) Alpha Industries, Inc. - Methuen, MA
1994	Harris Semiconductor - Palm Bay, FL (now Intersil Corporation) United Defense, L.P. Ground Systems Division - San Jose, CA Naval Undersea Warfare Center Division Keyport - Keyport, WA Mason & Hanger - Silas Mason Co., Inc. - Middletown, IA Kaiser Electronics - San Jose, CA U.S. Army Combat Systems Test Activity - Aberdeen, MD (now Aberdeen Test Center) Stafford County Public Schools - Stafford County, VA
1995	Sandia National Laboratories - Albuquerque, NM Rockwell Collins Avionics & Communications Division - Cedar Rapids, IA (now Rockwell Collins, Inc.) *(Resurvey of Rockwell International Corporation Collins Defense Communications)* Lockheed Martin Electronics & Missiles - Orlando, FL McDonnell Douglas Aerospace (St. Louis) - St. Louis, MO (now Boeing Aircraft and Missiles) *(Resurvey of McDonnell-Douglas Corporation McDonnell Aircraft Company)* Dayton Parts, Inc. - Harrisburg, PA Wainwright Industries - St. Peters, MO Lockheed Martin Tactical Aircraft Systems - Fort Worth, TX *(Resurvey of General Dynamics Fort Worth Division)* Lockheed Martin Government Electronic Systems - Moorestown, NJ Sacramento Manufacturing and Services Division - Sacramento, CA JLG Industries, Inc. - McConnellsburg, PA
1996	City of Chattanooga - Chattanooga, TN Mason & Hanger Corporation - Pantex Plant - Amarillo, TX Nascote Industries, Inc. - Nashville, IL Weirton Steel Corporation - Weirton, WV NASA Kennedy Space Center - Cape Canaveral, FL *Resurvey of Department of Energy, Oak Ridge Operations* - Oak Ridge, TN

1997	Headquarters, U.S. Army Industrial Operations Command - Rock Island, IL (now Operational Support Command) SAE International and Performance Review Institute - Warrendale, PA Polaroid Corporation - Waltham, MA Cincinnati Milacron, Inc. - Cincinnati, OH Lawrence Livermore National Laboratory - Livermore, CA Sharretts Plating Company, Inc. - Emigsville, PA Thermacore, Inc. - Lancaster, PA Rock Island Arsenal - Rock Island, IL Northrop Grumman Corporation - El Segundo, CA *(Resurvey of Northrop Corporation Aircraft Division)* Letterkenny Army Depot - Chambersburg, PA Elizabethtown College - Elizabethtown, PA Tooele Army Depot - Tooele, UT
1998	United Electric Controls - Watertown, MA Strite Industries Limited - Cambridge, Ontario, Canada Northrop Grumman Corporation - El Segundo, CA Corpus Christi Army Depot - Corpus Christi, TX Anniston Army Depot - Anniston, AL Naval Air Warfare Center, Lakehurst - Lakehurst, NJ Sierra Army Depot - Herlong, CA ITT Industries Aerospace/Communications Division - Fort Wayne, IN Raytheon Missile Systems Company - Tucson, AZ Naval Aviation Depot North Island - San Diego, CA *U.S.S. Carl Vinson* (CVN-70) - Commander Naval Air Force, U.S. Pacific Fleet Tobyhanna Army Depot - Tobyhanna, PA
1999	Wilton Armetale - Mount Joy, PA Applied Research Laboratory, Pennsylvania State University - State College, PA Electric Boat Corporation, Quonset Point Facility - North Kingstown, RI *Resurvey of NASA Marshall Space Flight Center* - Huntsville, AL Orenda Turbines, Division of Magellan Aerospace Corporation - Mississauga, Ontario, Canada
2000	Northrop Grumman, Defensive Systems Division - Rolling Meadows, IL Crane Army Ammunition Activity - Crane, IN Naval Sea Logistics Center, Detachment Portsmouth - Portsmouth, NH Stryker Howmedica Osteonics - Allendale, NJ
2001	The Tri-Cities Tennessee/Virginia Region - Johnson City, TN General Dynamics Armament Systems - Burlington, VT Lockheed Martin Naval Electronics & Surveillance Systems-Surface Systems - Moorestown, NJ Frontier Electronic Systems - Stillwater, OK
2002	U.S. Coast Guard, Maintenance and Logistics Command-Atlantic - Norfolk, VA U.S. Coast Guard, Maintenance and Logistics Command-Pacific - Alameda, CA Directorate for Missiles and Surface Launchers (PEO TSC-M/L) - Arlington, VA General Tool Company - Cincinnati, OH